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M.S. RESISTANCES

# HARMONIC FILTER RESISTORS

# DAMPING RESISTORS IN HARMONIC FILTERS

In order to control the impedance in a electrical system with harmonic current generation filter circuits are used. They allow to fix a low impedance at defined fixed frequency independent of the network.

In order to build such filters the traditional electro technical offers the use of capacitors and inductors. By connecting this two elements in various configuration a well defined frequency response can be achieved. How ever the available components do have a very high quality factor, that means very low losses. This results in a system which is also very susceptible for undesired resonance's, or poor performance with variable frequency.

In this cases resistors can help to improve the behavior. They act as damping elements in a oscillating system, similar to the shock absorbers in the suspension of a car, where the springs and the mass of the car can be compared to the reactors and the capacitors in the electrical system.

With adequate circuit design losses at fundamental frequency can be avoided and optimum results at harmonic frequency can be achieved. In general they smoothen the response at the tuning frequency in order to increase the immunity to frequency variation and component tolerances due to manufacturing and temperature. At the parallel resonance frequency they control the dynamic behavior of the filter in order to avoid critical amplification of residual non typical harmonics and general noise.

At this point a resistance with variable resistance value can have a significant positive influence on the filter

At low harmonic distortion the resistance shall have a low value. This increases the damping of the system during unpredictable transient phenomena in the network like energizing of parallel circuits, transformers or the filter itself. With a low value in the resistor the switch on transient of the filter can be kept very short and we have maximum security in the system.

At increasing harmonic currents the resistor should have a high value in order to reduce the impedance of the filter at the tuning frequency and improve the voltage quality for steady state harmonic current.

This behaviour can be achieved by using a resistor with a high positive thermal coefficient for the resistivity. At low harmonic loads the resistor does not have any loss and is therefore at a low value. With increasing absorption of harmonic currents the resistive value increases and the filter quality improves.

Now it is up to the designer to choose the right compromise between transient damping and harmonic absorption. But it general it can be said it is always useful to have a positive coefficient even if it is only for the transient of filter energizing.

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# HOW TO IMPROVE FILTER RESISTORS ?

The important parameters of resistors which can modify price and size of resistors.

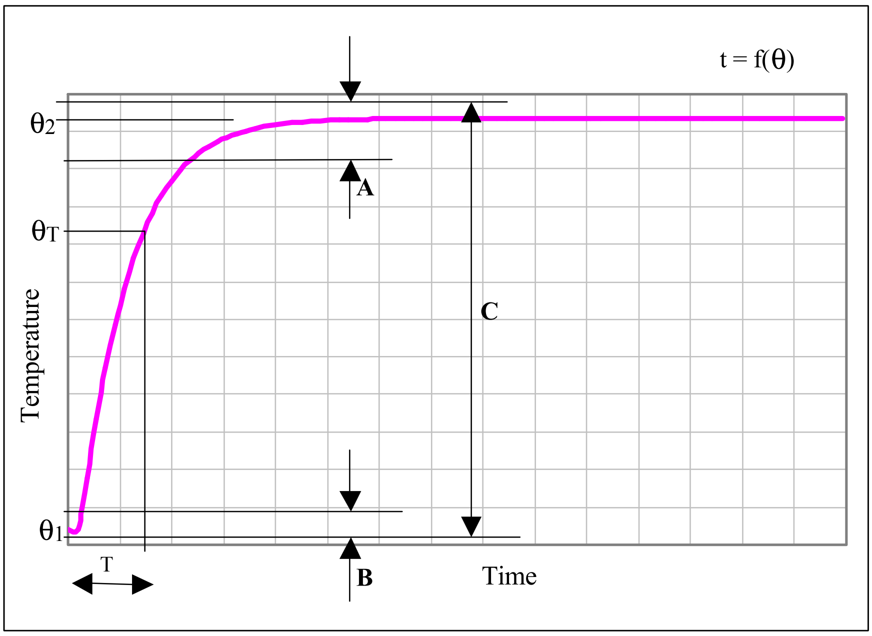
## *RESISTANCE VALUE AND TOLERANCE*

99% of Filter Resistors are made from Nickel Chromium stainless steel, depending on the type of live pads (grids, edge wound, mats), the resistance value can easily be obtained at ambient temperature. Selection of Alloy will depend on Required Ohmic Value Variation Between cold & Hot Stages. The Variation in Ohmic Values is governed by the Alloy Temperature Coefficient.

| ***Resistance Material*** | ***a □/ °C*** |
|---|---|
| ⇨ AISI 304<br>(18% Chromium - 10% Nickel) | 0,001 |
| ⇨ NICROFER 32/20<br>(20% Chromium - 32% Nickel) | 0,0004 |
| ⇨ NICROFER 63/20<br>(20% Chromium - 63% Nickel) | 0,00008 |
| ⇨OHMALLOY or<br>(Aluminium chromium steel) | 0,00012 |
| ⇨KONSTANTAN | 0,000022 |

## *TOLERANCE*

There are 3 kinds of tolerances.
By computer calculation and simulation based on laboratory tests results and data, A, B & C can be obtained easily.




- *A Tolerance of resistance value at operating stage*
- *B Tolerance of resistance value at ambient temperature*
- *C Tolerance of resistance value from cold to hot stage*
- *$q_1$ Ambient temperature ,$q_T$ = 63.2% of $q_2$*
- *$q_2$ Average temperature (maxi*
- *T Time constant*

## *TAPS ON RESISTOR*

The resistance value of Power resistor cannot be adjusted easily (it is not a variable rheostat).
Than adjustment must be made internally by modification of connections.
When different resistance values are given for the same power, resistor must be designed to withstand the same power with the lowest resistance value.
The other values are obtained by adding resistance elements.

***Example***

- Case 1 P = 40 kW - R = 10 ohms - I = 63.2 A
- Case 2 P = 40 kW - R = 15 ohms - I = 51.6 A
- Case 3 P = 40 kW - R = 20 ohms - I = 44 A

- ***Case 1 must be considered first.***

## *INDUCTANCE*

The "reasonable" inductance value can be easily obtained (from 50 to 500µH).
The inductance value can be adjusted to lowest value by using specific resistance material, internal arrangement.
Consequence : price increasing.

## *LOAD, OVER-LOAD & ENERGY PULSE*

The Filter Resistor as other components of Filter (capacitors, reactor) must withstand the same stress in terms of voltage, current and environment conditions with a thermal stress in addition due to energy dissipation.

This energizing is a combination of a permanent current $I_{rms}$

$$W = \int_0^\infty R.I_{rms}^2 \,.\, dt = m \,.\, c \,.\, \Delta q$$

$$Irms = \sqrt{I_1^2 + I_2^2 + In^2}$$

From time to time an additional overload as result of a temporary extra current.
In case of high overload and short time between events, the resistor will be designed to withstand the overload as continuous power. (Consequence : Price increasing.)

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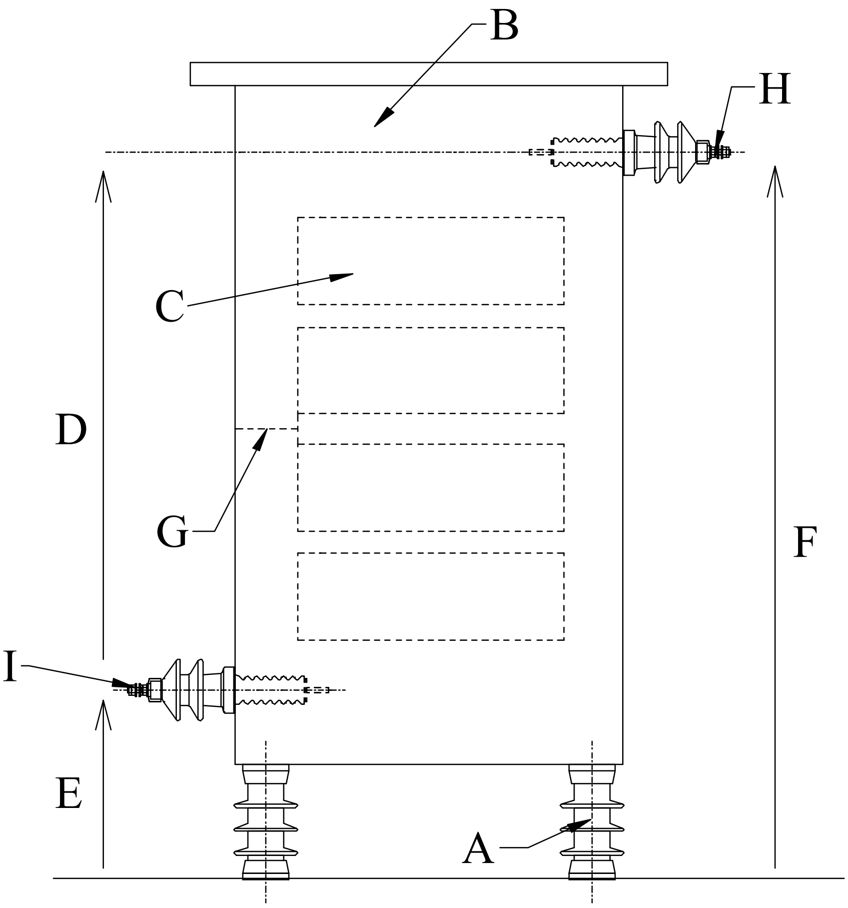
## *INSULATION OF RESISTOR AND BIL LEVEL*




*Typical design of Filter Resistor*

- *A outdoor insulators*
- *B housing of resistors under voltage*
- *C life parts of resistor*
- *D BIL level terminal to terminal*
- *E BIL level low voltage terminal to earth*
- *F BIL level high voltage terminal to earth*
- *G link connection between mid point of resistance and housing*
- *H In high voltage terminal bushing*
- *I Out low voltage terminal bushing*

The life parts comprise several resistor banks. One resistance bank can withstand up to $50kV_{BIL}$.

## *HOUSING FINISHING*

The Hot Dip Galvanizing finishing of housing is the best protection against corrosion or aggressive environment such as acid pollution.
For installation near the sea, the housing can be made from Nickel chrome stainless steel sheets AISI 316.
The Nickel Chromium stainless steel must be AISI 316 at least
We do not recommend painting housing.

| ***Finishing*** | ***Use & Protection*** |
|---|---|
| Hot dip Galvanizing | Very good corrosion resistance,<br>Very good acid pollution resistance,<br>Recommended for indoor & outdoor,<br>Recommended for installation near the sea. |
| Nickel Chrome stainless steel AISI 304 | Not recommended for installation near the sea (salt and humidity). |
| Nickel Chrome stainless steel AISI 316 | Recommended for installation near the sea. |
| Mill Galvanizing | Not recommended due to corrosion risk. |
| Paint | Not recommended because of painting destruction due to the elevation of temperature of housing and corrosion risk. |
| Mill Galvanizing & Paint | Better than paint only. |

## *SIDE BY SIDE OR STACKED PHASES*

In normal conditions the filter resistor must be installed side by side but if required, the phases can be designed to be stacked or installed in the top of capacitor banks to be specified at tender stage.